

A COMPARATIVE STUDY OF THE RESPIRATORY METABOLISM OF EXCISED BRAIN TISSUE OF MARINE TELEOSTS¹

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In recent years several investigators have studied the respiratory metabolism of fish brain tissue. Fuhrman *et al.* (1944) studied the metabolism of excised brain of the large-mouthed bass, *Huro salmoides*, at graded temperature levels. In 1950 the phenomena of brain tissue metabolic adaptation to temperature in the polar cod, *Boreogadus saida*, and the golden orie, *Idus melanotus*, were investigated by Peiss and Field. Freeman (1950), working with the goldfish, *Carassius auratus*, noted their brain metabolism during temperature acclimatization.

Certain physiological factors have been correlated with activity in marine fishes. Dawson (1933) showed that the more active fishes had a greater number of circulating immature erythrocytes than did less active species. Hall (1929, 1930) found that sluggish species not only consumed less oxygen but were capable of removing oxygen to lower tensions than could more active fishes. Hall and Gray (1929) and Gray and Hall (1930) found that in general the more active surface-feeding fishes had higher hemoglobin concentration and higher blood sugar level than did the sluggish bottom dwellers. Gray (1946, 1947) has pointed out a direct correlation between activity and the area of gill surface in marine teleosts.

It has seemed worthwhile to make a comparative study of the respiratory rate of excised brain tissue of marine teleosts to see if there might not be a correlation between brain metabolism and activity.

MATERIALS AND METHODS

Fishes were collected in the vicinity of the Duke University Marine Laboratory, Beaufort, N. C., and were maintained in the laboratory in aerated tanks supplied with running sea water. The procedures apply to all 17 species of marine fishes used in this study. Following exposure by cutting through the roof of the skull, all brain tissue anterior to the vagal lobes was removed, blotted quickly on filter paper, and weighed. The brain tissue was then ground in a dry mortar and taken up in a phosphate buffer of pH 7.5 (glass electrode) prepared by mixing 0.16 *M* KH_2PO_4 and 0.121 *M* NaPHO_4 . Sufficient buffer was added to bring the volume to 3.0 ml. and then the brei was transferred to a Warburg flask. The center wall of the respirometer flask contained both 0.2 ml. of 10% KOH and filter paper wicks. Time between the death of the animal and the beginning of the 10-minute period of thermal equilibration was kept constant at 10 minutes. Manometric measurements were made in a bath maintained at 30° C. Readings were taken at 10-minute intervals and were carried out for a minimum of 60 minutes. Results

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are expressed in terms of wet weight Q_{O_2} . Thus Q_{O_2} (wet weight) denotes micro-liters of oxygen consumed per gram of wet weight per minute. The water content of the brain tissue of some species was determined by drying to a constant weight at 105° C.

RESULTS

The rate of oxygen consumption of brain brei preparations of 17 species of marine teleost fishes determined at 30° C. is shown in Table I. The fishes are arranged in the table, not in the order of their activity, but according to their rate of brain tissue oxygen consumption. Although a sharp dividing line is not evi-

TABLE I
Oxygen consumption of brain breis of some marine teleost fishes

Species	No. of determinations	Mean Q_{O_2} wet weight	Standard deviation
Group I:			
Menhaden	8	14.19	3.66
<i>Brevoortia tyrannus</i>			
Mullet	10	13.52	1.46
<i>Mugil cephalus</i>			
Sea trout	9	12.53	2.66
<i>Cynoscion nebulosus</i>			
Sheepshead	7	11.67	1.80
<i>Archosargus probatocephalus</i>			
Cutlass	3	11.03	1.86
<i>Trichiurus lepturus</i>			
Group II:			
Sea bass	5	9.72	2.78
<i>Centropristus striatus</i>			
Pinfish	24	9.30	0.91
<i>Lagodon rhomboides</i>			
Croaker	8	9.04	4.15
<i>Micropogon undulatus</i>			
Pigfish	15	8.95	1.11
<i>Orthopristis chrysopterus</i>			
Silver perch	5	8.51	1.27
<i>Bairdiella chrysura</i>			
Spot	13	7.78	1.41
<i>Leiostomus xanthurus</i>			
Group III:			
Flounder	3	6.96	0.74
<i>Paralichthys dentatus</i>			
Spiny boxfish	1	6.69	—
<i>Chilomycterus schoepfii</i>			
Tongue fish	1	6.40	—
<i>Symphurus plagiusa</i>			
Lizard fish	2	6.01	0.01
<i>Synodus faetens</i>			
Toadfish	13	5.57	1.16
<i>Opsanus tau</i>			
Hogchocker	1	5.14	—
<i>Achirus fasciatus</i>			

dent, the fishes are arbitrarily divided into three groups for convenience of discussion. Group I consists of those species which are the most active and are characterized by constant swimming movements. In Group II are those which seem to exhibit less activity than Group I, but are distinctly more active than the bottom-dwelling species of Group III.

Caution should be exercised in viewing too strictly the exact relationship of a few species because of the small number of determinations, especially in the case of the spiny boxfish which is not a typical bottom-dwelling species. However, these clearly demonstrated the tendency of the more sluggish fishes to have a slower rate of oxygen consumption of brain breis and therefore should be included. That the variation of metabolic rate of brain tissue was greater for certain species than for others is evident from the standard deviation obtained. Data for the croaker had a large standard deviation, whereas the standard deviation was small in the case of the pinfish.

When the weight of the pinfish (range 14.5–50 grams) was charted against the rate of oxygen consumption of brain tissue, no correlation was apparent. Similarly, when the length of the toadfish (range 12–40 centimeters) was plotted against the rate of oxygen consumption, no positive correlation was noted. Therefore, it would seem that within the size range of the fish used in this study, the rate of oxygen consumption of brain brei was independent of the weight or the length of the individual, and that the brain tissue of the younger or smaller individual of a species generally consumed about the same amount of oxygen per unit weight as the older or larger specimens.

The results of the brain tissue water-content determinations of 7 species of marine fishes are shown in Table II. In general, the water content is similar in all of the species examined.

TABLE II
Brain tissue water content of 7 species of marine fishes

Species	No. of determinations	Average	Range
Mullet	3	79.02%	77.05–80.90%
Pigfish	3	77.62%	76.33–79.12%
Pinfish	8	79.81%	76.92–82.18%
Sea bass	2	77.08%	76.74–77.42%
Sheepshead	2	76.28%	75.08–77.48%
Spot	7	78.58%	75.00–80.83%
Toadfish	4	78.27%	77.50–79.12%

DISCUSSION

From the results of this study, a positive correlation is evident between the activity of marine teleost fishes and the oxygen consumption of brain breis.

Due to geographical difference in the distribution and relative abundance of fishes during the summer months at Beaufort, N. C., where the present study was made, and Woods Hole, Mass., where most of the early work reported in the literature was done, it is not possible to compare every species, but some species are common to both locations.

Hall and Gray (1929) and Gray and Hall (1930) found that those fishes which had the highest hemoglobin concentration and highest blood sugar level were considered to be the most active. Only two species of fishes investigated by them were used in the present investigation, the menhaden and the toadfish. The menhaden had a higher hemoglobin concentration and blood sugar level than the toadfish. In the present study, the rate of oxygen consumption of excised menhaden brain was distinctively higher than that of the toadfish. Dawson (1933) found the menhaden, as well as other active fishes, to have a greater number of immature circulating erythrocytes than the more sluggish forms, including the toadfish.

In respect to respiratory studies involving marine fishes, Hall and Gray (1929) point out that the menhaden has a higher rate of oxygen consumption than the more sluggish toadfish. Gray (1947) found that the menhaden has about 10 times more gill area than the toadfish per gram of body weight and 15 times more gill area per square centimeter of body surface. A comparison of other species shows that in general a rating of activity based on gill area per gram of weight or per square centimeter of body surface (Gray, unpublished) would agree with an activity rating based on oxygen consumption of brain tissue. A notable exception is the spiny boxfish but as stated previously only one determination was made on this species and more tests may alter the relative rating of this form.

Thus, when comparing the results of these various physiological indices of activity, as reported by other workers, with the results of the present study, it may be noted that there is a positive relationship between the various indices of activity and the data of this paper.

In general the results of the rate of brain tissue oxygen consumption in the present paper are similar to those values obtained by other workers (Fuhrman *et al.*, 1944; Peiss and Field, 1950; and Freeman, 1950). The influence of thermal acclimatization on the rate of oxygen consumption of brain tissue of fish was studied by Peiss and Field (1950) and Freeman (1950). They reported that at a common temperature the brain metabolism was highest for fish acclimatized at the lowest temperatures. No marked variation in respiration data was observed when comparing results of tests conducted in June with later determinations, as is evident in the case of the pinfish. The 24 determinations on this species were made at scattered intervals in June, July and August. The maximum-minimum water temperature taken in the Beaufort Channel from June 17 until August 20, 1952 showed an increase from readings of 80°–79° F. on June 17 to a high of 90°–87° F. on June 28. This was followed by a period of temperature decline and on July 5 the respective readings were 82°–76° F. During the month of August the highest reading was 84° F. and the lowest was 80° F. Thus it would seem that within the narrow temperature range at Beaufort during the period of this investigation no acclimatization effect of brain tissue was observed.

Although some workers have noted a decrease of tissue respiration with increase of body weight (Kayser, Le Breton and Schaeffer, 1925, brains of rats, pigeons and fowls; Hawkins, 1928, rat liver slices; Field *et al.*, 1937, rabbit lens; and Weymouth *et al.*, 1944, mid-gut gland of kelp crab), a similar relationship was not noted in the case of the pinfish and toadfish where the Q_{O_2} appeared to be independent of body weight and body length. However, Grafe (1925) and Terroine and Roche (1925) found that any differences in tissue metabolism of large and

small homoeothermic animals disappear when the tissues are removed from the body of the animal. Recently, Krebs (1950) reported that there is not a simple correlation between body size and Q_{O_2} within the same species, and, in general, tissues of larger species have lower Q_{O_2} values than homologous values of smaller species.

SUMMARY

1. The oxygen consumption of brain tissue of 17 species of marine teleost fishes was determined at 30° C.

2. A positive correlation exists between rate of oxygen consumption and activity of fishes. The more active fishes, like the menhaden, had a higher Q_{O_2} than the sluggish fishes, such as the toadfish.

3. In general, when comparing results of this paper with various physiological indices of activity, a positive relationship was noted.

4. Q_{O_2} of brain tissue of the pinfish and the toadfish were independent of body weight and body length.

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